

# ANNEX J

## Methodology for Estimating Emissions from International Bunker Fuels used by the U.S. Military

Bunker fuel emissions estimates for the Department of Defense (DoD) were developed using data primarily generated by the Defense Energy Support Center for aviation and naval fuels (DESC 2002). The DESC of the Defense Logistics Agency (DLA) prepared a special report based on data in the Defense Fuels Automated Management System (DFAMS). DFAMS contains data for 1995 through 2001, but the data set was not complete for years prior to 1995. Fuel quantities for 1990 to 1994 were estimated based on a back-calculation of the 1995 DFAMS values using DLA aviation and marine fuel procurement data. The back-calculation was refined in 1999 to better account for the jet fuel conversion from JP4 to JP8 that occurred within the DoD between 1992 and 1995.

### Step 1: Omit Extra-Territorial Fuel Deliveries

Beginning with the complete DFAMS data set for each year, the first step in the development of DoD related emissions from international bunker fuels was to identify data that would be representative of international bunker fuel consumption as that term is defined by decisions of the UNFCCC (i.e., fuel sold to a vessel, aircraft, or installation within the United States or its territories and used in international maritime or aviation transport). Therefore, fuel data were categorized by the location of fuel delivery in order to identify and omit all extra-territorial fuel transactions/deliveries (i.e., sales abroad).

### Step 2: Allocate JP8 between Aviation and Land-based Vehicles

As a result of DoD<sup>1</sup> and NATO<sup>2</sup> policies on implementing the Single Fuel For the Battlefield concept, DoD activities have been increasingly replacing diesel fuel with JP8 (a type of jet fuel) in compression ignition and turbine engines in land-based equipment. Based on this concept and examination of all data describing jet fuel used in land-based vehicles, it was determined that a portion of JP8 consumption should be attributed to ground vehicle use. Based on available Service data and expert judgment, it was determined that a small fraction of the total JP8 should be reallocated from the aviation subtotal to a new land-based jet fuel category for 1997 and subsequent years. As a result of this reallocation, the JP8 use reported for aviation will be reduced and the total fuel use for land-based equipment will increase. DoD's total fuel use will not change.

Table J-1 displays DoD's fuel use within the United States. The figure represents data after the completion of Steps 1 and 2, summarized by fuel type. Table J-1 also reflects the adjustments for JP8 used in land-based equipment, as described above.

### Step 3: Omit Land-Based Fuels

Navy and Air Force land-based fuels (i.e., fuel not used by ships or aircraft) were also omitted for the purpose of calculating international bunker fuels. The remaining fuels, listed below, are potential DoD international bunker fuels.

- Marine: naval distillate fuel (F76), marine gas oil (MGO), and intermediate fuel oil (IFO).
- Aviation: jet fuels (JP8, JP5, JP4, JAA, JA1, and JAB).

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<sup>1</sup> DoD Directive 4140.43, Fuel Standardization, 1998; DoD Directive 4140.25, DoD Management Policy for Energy Commodities and Related Services, 1999.

<sup>2</sup> NATO Standard Agreement NATO STANAG 4362, Fuels for Future Ground Equipments Using Compression Ignition or Turbine Engines, 1987.

#### **Step 4: Omit Fuel Transactions Received by Military Services that are not Considered to be International Bunker Fuels**

Next, the records were sorted by Military Service. The following assumptions were used regarding bunker fuel use by Service, leaving only the Navy and Air Force as users of military international bunker fuels.

- Only fuel delivered to a ship, aircraft, or installation in the United States can be a potential international bunker fuel. Fuel consumed in international aviation or marine transport should be included in the bunker fuel estimate of the country where the ship or aircraft was fueled. Fuel consumed entirely within a country's borders is not bunker fuel.
- Based on discussions with the Army staff, only an extremely small percentage of Army aviation emissions, and none of its watercraft emissions, qualified as bunker fuel emissions. The magnitude of these emissions was judged to be insignificant when compared to Air Force and Navy emissions. Based on this, Army bunker fuel emissions were assumed to be zero.
- Marine Corps aircraft operating while embarked consume fuel reported as delivered to the Navy. Bunker fuel emissions from embarked Marine Corps aircraft were reported in the Navy bunker fuel estimates. Bunker fuel emissions from other Marine Corps operations and training were assumed to be zero.
- Bunker fuel emissions from other DoD and non-DoD activities (i.e., other federal agencies) that purchase fuel from DESC were assumed to be zero.

#### **Step 5: Determine Bunker Fuel Percentages**

Next it was necessary to determine what percent of the marine and aviation fuels were used as international bunker fuels. Military aviation bunkers include international operations (i.e., sorties that originate in the United States and end in a foreign country), operations conducted from naval vessels at sea, and operations conducted from U.S. installations principally over international water in direct support of military operations at sea (e.g., anti-submarine warfare flights). For the Air Force, a bunker fuel weighted average was calculated based on flying hours by major command. International flights were weighted by an adjustment factor to reflect the fact that they typically last longer than domestic flights. In addition, a fuel use correction factor was used to account for the fact that transport aircraft burn more fuel per hour of flight than most tactical aircraft. The Air Force bunker fuel percentage was determined to be 13.2 percent. This percentage was multiplied by total annual Air Force aviation fuel delivered for U.S. activities, producing an estimate for international bunker fuel consumed by the Air Force. The Naval Aviation bunker fuel percentage of total fuel was calculated using flying hour data from *Chief of Naval Operations N88F, Flying Hour Projection System* (N42 1991, 1996, 1999), and estimates of bunker fuel percent of flights provided by the fleet. The Naval Aviation bunker fuel percentage, determined to be 40.4 percent, was multiplied by total annual Navy aviation fuel delivered for U.S. activities, yielding total Navy aviation bunker fuel consumed.

For marine bunkers, fuels consumed while ships are underway are assumed to be bunker fuels. In 2000, the Navy reported that 79 percent of vessel operations were underway, while the remaining 21 percent of operations occurred in port (i.e., pierside). Therefore, the Navy maritime bunker fuel percentage was determined to be 79 percent. The percentage of time underway may vary from year-to-year. For example, for years prior to 2000, the bunker fuel percentage was 87 percent. Table J-2 displays DoD's aviation bunker fuel use and Table J-3 displays DoD's maritime bunker fuel use.

#### **Step 6: Calculate Emissions from Military International Bunker Fuels**

Bunker fuel totals were multiplied by appropriate emission factors to determine greenhouse gas emissions (see Table J-4 and Table J-5).

The rows labeled 'U.S. Military' and 'U.S. Military Naval Fuels' within Table 2-39 and Table 2-40 in the Energy Chapter were based on the international bunker fuel totals provided in Table J-2 and Table J-3, below. Total CO<sub>2</sub> emissions from military bunker fuels are presented in Table J-6. Carbon dioxide emissions from aviation bunkers and distillate marine bunkers presented in Table 2-38 are the total of military plus civil aviation and civil marine bunker fuels, respectively. The military component of each total is based on fuels tallied in Table J-2 and Table J-3.

At the completion of the 2000 DoD international bunker fuel estimate, it was apparent that the Navy maritime data provided by DESC were abnormal compared to those data for each year from 1995 to 1999. The Navy fuels and logistics office identified a separate data set, which was used as the source for the 2000 inventory, but Navy continued to investigate the 2000 DESC maritime data, which Navy fuels experts considered an anomaly. DESC determined that a few records in the 2000 maritime data set contained errors that were traced back to the DFAMS database system. The DFAMS program was not originally designed to account for open market bunkers transactions, but was later modified to include these purchases, which resulted in some system complications. For example, there are several places in the program where the fuel quantity must be adjusted to allow for an assumed decimal (i.e., divided by 100). Because the adjustment does not occur automatically in the open market bunkers purchases section of the program, queried quantities would reflect 100 times their actual value. DESC reported that this assumed decimal error would have impacted some of the 2000 data for MGO and F76; however, this error should not be present in previous years' data. DESC ran a new query that produced correction amounts for the 2000 MGO and F-76 fuel data set. This query produced results consistent with data from 1995 to 1999, and the 2001 DoD Inventory has been revised accordingly to reflect the 2000 DESC data.

**Table J-1: Transportation Fuels from Domestic Fuel Deliveries<sup>a</sup> (Million Gallons)**

Vehicle Type/Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
<b>Aviation</b>	<b>4,598.45</b>	<b>4,562.84</b>	<b>3,734.49</b>	<b>3,610.85</b>	<b>3,246.23</b>	<b>3,099.93</b>	<b>2,941.91</b>	<b>2,683.37</b>	<b>2,736.95</b>	<b>2,628.57</b>	<b>2,655.54</b>	<b>2,889.45</b>
Total Jet Fuels	4,598.42	4,562.81	3,734.46	3,610.83	3,246.21	3,099.91	2,941.90	2,683.37	2,736.93	2,628.56	2,655.53	2,889.42
JP8	285.75	283.54	234.46	989.38	1,598.07	2,182.80	2,253.15	2,069.74	2,118.08	2,059.80	2,113.79	2,315.06
JP5	1,025.36	1,017.42	832.71	805.14	723.84	691.22	615.83	552.77	515.56	505.50	472.10	503.17
Other Jet Fuels	3,287.31	3,261.86	2,667.29	1,816.30	924.30	225.89	72.92	60.86	103.29	63.25	69.65	71.19
Aviation Gasoline	0.03	0.03	0.02	0.02	0.02	0.02	0.01	+	0.02	0.01	0.01	0.03
<b>Marine</b>	<b>686.80</b>	<b>632.61</b>	<b>646.18</b>	<b>589.37</b>	<b>478.59</b>	<b>438.91</b>	<b>493.34</b>	<b>639.85</b>	<b>674.22</b>	<b>598.86</b>	<b>454.36</b>	<b>418.45</b>
Middle Distillate (MGO)	+	+	+	+	+	+	38.52	47.48	51.14	49.22	48.29	33.02
Naval Distillate (F76)	686.80	632.61	646.18	589.37	478.59	438.91	448.96	583.41	608.39	542.94	397.97	369.14
Intermediate Fuel Oil (IFO) <sup>b</sup>	+	+	+	+	+	+	5.86	8.95	14.69	6.70	8.09	16.28
<b>Other<sup>c</sup></b>	<b>717.11</b>	<b>590.41</b>	<b>491.68</b>	<b>415.10</b>	<b>356.06</b>	<b>310.95</b>	<b>276.90</b>	<b>265.67</b>	<b>261.28</b>	<b>262.64</b>	<b>257.07</b>	<b>120.89</b>
Diesel	93.04	97.88	102.96	108.31	113.94	119.86	126.09	132.64	139.53	146.78	126.63	26.65
Gasoline	624.07	492.53	388.72	306.78	242.12	191.09	150.81	119.02	93.94	74.14	74.81	24.72
Jet Fuel <sup>d</sup>	+	+	+	+	+	+	+	13.91	27.81	41.72	55.62	69.53
<b>Total (Including Bunkers)</b>	<b>6,002.37</b>	<b>5,785.85</b>	<b>4,872.34</b>	<b>4,615.32</b>	<b>4,080.89</b>	<b>3,849.78</b>	<b>3,712.15</b>	<b>3,588.79</b>	<b>3,672.45</b>	<b>3,490.06</b>	<b>3,366.97</b>	<b>3,428.78</b>

Note: Totals may not sum due to independent rounding.

<sup>a</sup> Includes fuel consumption in the United States and U.S. Territories.

<sup>b</sup> Intermediate fuel oil (IFO 180 and IFO 380) is a blend of distillate and residual fuels. IFO is used by the Military Sealift Command.

<sup>c</sup> Prior to 2001, gasoline and diesel fuel totals were estimated using data provided by the military Services for 1990 and 1996. The 1991 through 1995 data points were interpolated from the Service inventory data. Growth factors used for other diesel and gasoline were 5.2 and -21.1 percent, respectively. The 1997 through 1999 gasoline and diesel fuel data were initially extrapolated from the 1996 inventory data. Data sets for other diesel and gasoline consumed by the military in 2000 were initially estimated based on ground fuels consumption trends. This method produced a result that was more consistent with expected consumption for 2000. In 2001, other gasoline and diesel fuel totals were generated by DESC. Prior estimates for JP8 use from 1997 through 2000 were adjusted to reflect the estimated consumption of JP8 (jet fuel) being used as a replacement for diesel fuel in land-based vehicles and equipment. DoD is increasing its use of JP8 in land-based vehicles and equipment as the Department implements its policy of using a single fuel (JP8) for all tactical equipment. Concurrently, the amount of JP8 reduced in the aviation totals was added to a new JP8 line within the "Other" category of the table. This reallocation of JP8 increases the amount of ground fuel use being reported in the Other category.

<sup>d</sup> The fraction of jet fuel consumed in land-based vehicles was estimated using Service data, DESC data, and expert judgment.

+ Does not exceed 0.005 million gallons.

**Table J-2: Total U.S. Military Aviation Bunker Fuel (Million Gallons)**

Fuel Type/Service	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
<b>JP8</b>	<b>56.74</b>	<b>56.30</b>	<b>46.40</b>	<b>145.33</b>	<b>223.99</b>	<b>300.40</b>	<b>308.81</b>	<b>289.24</b>	<b>300.86</b>	<b>293.04</b>	<b>296.50</b>	<b>327.31</b>
Navy	56.74	56.30	46.08	44.56	40.06	38.25	39.84	44.58	49.14	48.45	44.04	62.10
Air Force	+	+	0.32	100.77	183.93	262.15	268.97	244.66	251.72	244.59	252.46	265.21
<b>JP5</b>	<b>370.53</b>	<b>367.66</b>	<b>300.92</b>	<b>290.95</b>	<b>261.57</b>	<b>249.78</b>	<b>219.40</b>	<b>194.16</b>	<b>184.38</b>	<b>175.37</b>	<b>160.35</b>	<b>169.73</b>
Navy	365.29	362.46	296.66	286.83	257.87	246.25	216.09	191.15	181.36	170.59	155.60	163.68
Air Force	5.25	5.21	4.26	4.12	3.70	3.54	3.31	3.01	3.02	4.77	4.74	6.05
<b>JP4</b>	<b>420.77</b>	<b>417.52</b>	<b>341.40</b>	<b>229.64</b>	<b>113.11</b>	<b>21.50</b>	<b>1.05</b>	<b>0.05</b>	<b>0.03</b>	<b>0.02</b>	<b>0.01</b>	<b>0.02</b>
Navy	0.02	0.02	0.02	0.02	0.01	0.01	+	+	+	+	+	+
Air Force	420.75	417.50	341.39	229.62	113.10	21.49	1.05	0.05	0.03	0.02	0.01	0.02
<b>JAA</b>	<b>13.70</b>	<b>13.60</b>	<b>11.13</b>	<b>10.76</b>	<b>9.67</b>	<b>9.24</b>	<b>10.27</b>	<b>9.42</b>	<b>10.84</b>	<b>10.78</b>	<b>12.46</b>	<b>12.61</b>
Navy	8.45	8.39	6.86	6.64	5.97	5.70	6.58	5.88	6.63	6.32	7.95	8.02
Air Force	5.25	5.21	4.27	4.12	3.71	3.54	3.69	3.54	4.21	4.47	4.51	4.59
<b>JA1</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>0.01</b>	<b>+</b>	<b>0.03</b>	<b>0.13</b>
Navy	+	+	+	+	+	+	+	+	+	+	0.02	0.02
Air Force	+	+	+	+	+	+	+	+	0.01	+	0.01	0.11
<b>JAB</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>
Navy	+	+	+	+	+	+	+	+	+	+	+	+
Air Force	+	+	+	+	+	+	+	+	+	+	+	+
<b>Navy Subtotal</b>	<b>430.50</b>	<b>427.17</b>	<b>349.62</b>	<b>338.04</b>	<b>303.91</b>	<b>290.21</b>	<b>262.51</b>	<b>241.61</b>	<b>237.13</b>	<b>225.36</b>	<b>207.61</b>	<b>233.82</b>
<b>Air Force Subtotal</b>	<b>431.25</b>	<b>427.91</b>	<b>350.23</b>	<b>338.63</b>	<b>304.44</b>	<b>290.72</b>	<b>277.02</b>	<b>251.26</b>	<b>258.99</b>	<b>253.85</b>	<b>261.74</b>	<b>275.98</b>
<b>Total</b>	<b>861.75</b>	<b>855.08</b>	<b>699.85</b>	<b>676.68</b>	<b>608.35</b>	<b>580.93</b>	<b>539.53</b>	<b>492.87</b>	<b>496.12</b>	<b>479.21</b>	<b>469.35</b>	<b>509.80</b>

+ Does not exceed 0.005 million gallons.

Note: Totals may not sum due to independent rounding.

**Table J-3: Total U.S. DoD Maritime Bunker Fuel (Million Gallons)**

Marine Distillates	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Navy - MGO	+	+	+	+	+	+	30.34	35.57	31.88	39.74	23.83	22.50
Navy - F76	522.37	481.15	491.47	448.27	364.01	333.82	331.88	441.65	474.23	465.97	298.61	282.59
Navy - IFO	+	+	+	+	+	+	4.63	7.07	11.61	5.29	6.39	12.87
<b>Total</b>	<b>522.37</b>	<b>481.15</b>	<b>491.47</b>	<b>448.27</b>	<b>364.01</b>	<b>333.82</b>	<b>366.85</b>	<b>484.29</b>	<b>517.72</b>	<b>511.00</b>	<b>328.83</b>	<b>317.96</b>

+ Does not exceed 0.005 million gallons.

Note: Totals may not sum due to independent rounding.

**Table J-4: Aviation and Marine Carbon Contents (Tg Carbon/QBtu) and Fraction Oxidized**

Mode (Fuel)	Carbon Content Coefficient	Fraction Oxidized
Aviation (Jet Fuel)	variable	0.99
Marine (Distillate)	19.95	0.99
Marine (Residual)	21.49	0.99

**Table J-5: Annual Variable Carbon Content Coefficient for Jet Fuel (Tg Carbon/QBtu)**

Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jet Fuel	19.40	19.40	19.39	19.37	19.35	19.34	19.33	19.33	19.33	19.33	19.33	19.33

**Table J-6: Total U.S. DoD CO<sub>2</sub> Emissions from Bunker Fuels (Tg CO<sub>2</sub> Eq.)**

Mode	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aviation	8.2	8.1	6.6	6.4	5.8	5.6	5.2	4.8	4.8	4.6	4.5	4.9
Marine	5.2	4.8	4.9	4.5	3.7	3.4	3.7	4.9	5.2	5.1	3.3	3.2
<b>Total</b>	<b>13.4</b>	<b>12.9</b>	<b>11.6</b>	<b>10.9</b>	<b>9.5</b>	<b>8.9</b>	<b>8.9</b>	<b>9.6</b>	<b>10.0</b>	<b>9.8</b>	<b>7.8</b>	<b>8.1</b>

Note: Totals may not sum due to independent rounding.